FLUID-STRUCTURE INTERACTION IN WATER TANKS: DYNAMIC ASSESSMENT

Mr.K.A.S.V.R.Sai Phani Kumar [1], Dr.A.Padmanabham [2], Mr.V.N.V.Radha Krishna Murty [3,]
Assistant Professor[1],Assistant Professor[2,3,]
Mail id:saifanikumar@gmail.com, Mail Id:apnabham@gmail.com, Mail Id:radhakrishna.veluri@gmail.com,
Department of Physics and Chemistry,
B.V.Raju College,Vishnupur, Bhimavaram,
DNR College of Engineering and Technology, Bhimavaram,

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ABSTRACT
Due to increased population and growth of cities, the number of raised water tanks servicing the demand urban \swater system is on the rise. As it has been indicated in the Iranian code of practise for Earthquake /2800 due \sof the necessity of sanitation and hygiene water tanks have been recognised as vital constructions during the unforeseen occurrences such as earthquake. There is a high anticipation not to observe any phase out for their serviceability following the earthquake. Because of the presence of fluid with various behavioural features of structures containing it Because the most part of mass of tanks are positioned in a great distance from their foundation, the behaviour of these sorts of structures in comparing with conventional structures are more sophisticated. In this study, cylindrical concrete water tanks, which feature a central shaft, have been examined with consideration the influence of the structure's contact with water via accurate execution of boundary constraints on the interface between fluid and structure. Also considering the volume of water in the tank and their response under recorded acceleration of varied earthquakes utilising finite element approach. The findings were then compared with proposed ways by Iranian code /2800, which shows a significant variation between the approaches given.

1. INTRODUCTION

The behaviour of liquid storage tanks during earthquakes is more significant than the economic worth of the tanks and their contents, which are crucial buildings in the water, oil and gas industries. Firefighting water, for example, must be available in the event of an earthquake, and utility infrastructure must be operable to satisfy these needsor satisfy the needs of the public as a source of drinking water. In light of these factors, serviceability is now the primary design consideration is taken into account in the majority of these constructions. It is crucial to have a clear grasp of how seismically vulnerable these buildings are.Safety goals and construction and maintenance expenses must be balanced.The interaction between fluids and these structures is a key issue in the understanding and design of these systems. And organisation. It is very difficult to predict the analytical response of coupled field systems. Most of the time, Numerical approaches, such as the finite element method, are at the heart of many research. Concrete water tanks with central shafts are analysed numerically in this work by employing finite elements. Software component that takes into account fluid-structure interaction.

2.THEORY

There is a wide range of methods for analysing the fluid-structure interaction. a) Added mass technique, b) The Eulerian-Lagrangian method, and c) The Lagrangian-Lagrangian method are all examples of these

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approaches.The fluid mass is introduced to the structure at the contact, and the structure is subjected to stress.a dynamic examination This approach considers the fluid's compressibility and stiffness as well as the structure's lexibility.are often overlooked. In 2- and 3-dimensional constructions, this approach is straightforward to employ, however the outcomes areFrequently, there are significant mistakes.The major goal of the second technique is to solve the governing equation for the fluid and structural domains. governing equation of fluid domain for an ideal, homogenous, inviscid, compressible and irrotational flow in term of velocity potential variable, φ , is:

$$\nabla^2\phi = \frac{1}{C^2}\frac{\partial^2\phi}{\partial t^2} \quad (2.1)$$

where C is the velocity of acoustic waves. By this assumption that fluid is incompressible, the Eqn.1 is conformed to Laplace Eqn.2.

$$\nabla^2\phi = 0 \quad (2.2)$$

It is possible to represent fluid dynamics in terms of time by solving Eqn.1 or Eqn.2 for fluid domains in terms of variables P and/or, which are pressure variables.Equations for the coupled field system of nodal displacement are required for the structural domain since the needed variable is nodal displacement.There will be an asymmetrical relationship between fluid and structure, making a simple solution difficult.Third, a particle has been taken into account in terms of time and variables for fluid and structural domains isIn the finite element approach, there is a nodal displacement. There is a major benefit to using this strategy because of the utilisation of the same toolssolving just this motion equation, we get displacement, pressure, and stress values for the fluid and the structure domain.Figures have been drawn out for both fluid and structure.The Langrage-Lagrange approach is being utilised to simulate fluid-structure interaction in this study.In the ANSYS programme, the Fluid80 and Shell63 elements are utilised for fluid and structural analysis.contains eight nodes with three degrees of freedoms in each node and Shell63 element has four nodes with six degrees ofEach node has flexibility.This study is based on the following assumption:1-The foundation of construction is supposed to be sturdy, 2-The tank and the water are assumed to have a linear andThe ability to change shape. Material qualities of concrete and water are presented in Table.1 and the finite element characteristicsFigure 1 shows the reservoir's geometry.Table shows that there are 1.The number of fluids and structures is shown in Table 2.sensitivity analysis of displacement is used for both static and dynamic analysis in order to acquire the elements.

Table 1 Material properties

water			Concrete		
Kinematics viscosity (m^2/s)	Specific mass (kg/m^3)	Bulk modulus (N/m^2)	Poison ratio	Specific mass (kg/m^3)	Modulus of Elasticity (N/m^2)
0.005	1000	2.2e9	0.27	2400	2e10

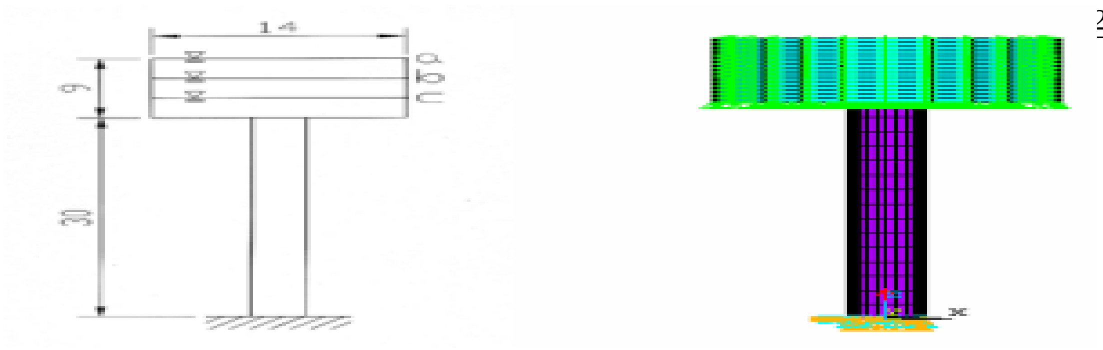


Figure 1 Finite element model of elevated water tanks.

Table 2 Geometric characteristic of tank

Reservoir of tank			shaft			Number of elements		Number of nodes	
thickness of wall (m)	diameter of wall (m)	height of wall	thickness of wall	diameter of wall	height of wall	Fluid	tank	Fluid	tank
0.3	14	9	0.5	3	30	3135	929	25080	3716

STATIC RESULT AND DISCUSSION

In order to study of modeling proportion, displacement and hydrostatic pressure are compared by using of theoretical and finite element methods. Eqn.3 and Eqn.4 are used to calculate the result of fluid weight as shown in Figure .2. To compare of this result with finite element one, the wall of tank are assumed to be rigid. The results are shown in Figures 3 and 4, which show a relatively compatibility between numerical and theoretical methods.

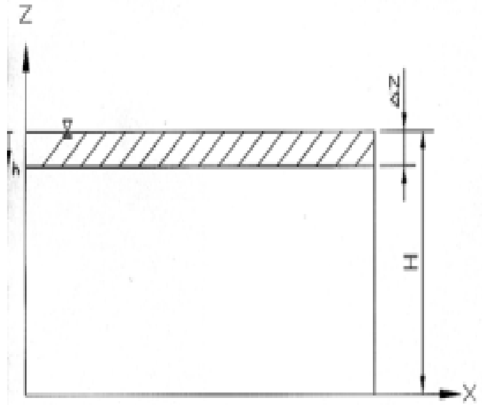


Figure 2 Tank with water

$$U_z = \frac{1}{k}\int_H^h \gamma z dz = \frac{\gamma}{k}\left[\frac{z^2}{2}\right]_H^h = \frac{-\rho g}{2k}\left[H^2 - h^2\right] \quad (3.1)$$

$$P = \gamma h \quad (3.2)$$

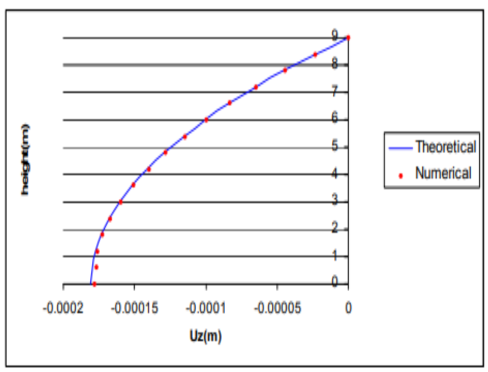


Figure3 Displacement variation along the height of water for theoretical and numerical methods

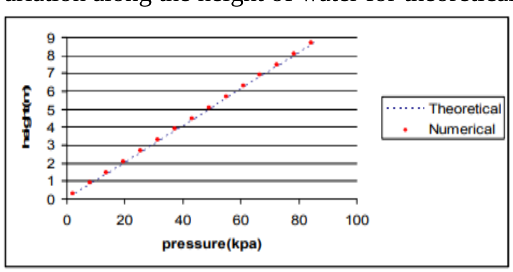


Figure4 Hydrostatic pressure variation along the height of water from theoretical and numerical methods

By solving eigen-value Eqn.5 for tank with different elevation of water (Empty, 3 1 Full, 3 2 Full, Full), the natural periods of system are obtained. A summary of the calculation results is listed in Table 3. While the mode shapes are shown in Figure.5.

$$[k][\phi] = [M][\phi][\Omega^2] \quad (4.1)$$

Table 3 periods of system with different elevation of water

Mode number	Period (sec)			
	Empty	$\frac{1}{3}$ Full	$\frac{2}{3}$ Full	Full
1	1.608	2.42	2.95	3.175
2	1.608	2.42	2.95	3.175
3	0.626	0.669	0.67	0.466
4	0.626	0.669	0.67	0.2
5	0.491	0.491	0.49	0.2
6	0.336	0.36	0.48	0.05

Using Eqn.7 and Eqn.8 with the assumption that the damping ratio is 0.05 for the two initial modes, the damping matrix and may be derived using the equations Eqn.6 and Eqn.7. Table.4 summarises these findings.

$$[c] = \alpha[M] + \beta[k] \quad (4.2)$$

$$\beta = \frac{2(\xi_i w_i - \xi_j w_j)}{(w_i^2 - w_j^2)} \quad (4.3)$$

$$\alpha + \beta w_i^2 = 2 w_i \xi_i \quad (4.4)$$

Whereα,β are coefficients related to mass and stiffness matrices i wj w , are periods of i and j modes. i j ξ ,ξ are damping ratio of i and j nodes.

PERIOD OF SYSTEM RELATED TO IRANIAN CODE/2800 In Iranian

Table.4 Data for α and β with $(\xi = 0.05)$

water elevation	Empty	$\frac{1}{3}$ Full	$\frac{2}{3}$ Full	Full
α	0.281	0.203	0.177	0.152
β	0.0072	0.0086	0.009	0.0093

PERIOD OF SYSTEM RELATED TO IRANIAN CODE/2800

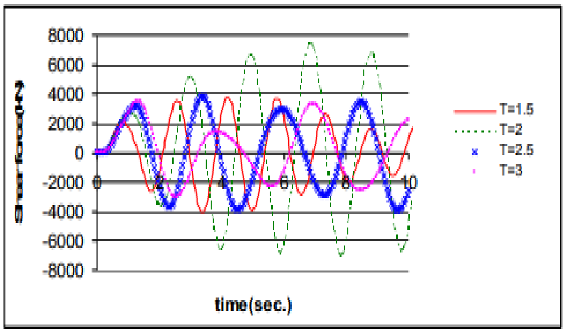
In Iranian code/2800, elevated water tanks are modeled with lumped mass in the end of slender cantilever. These results are summarized in Table.5.

Empty	$\frac{1}{3}$ Full	$\frac{2}{3}$ Full	Full
1.25	1.75	2.138	2.466

From Table.5, It is observed that periods calculated by Iranian code/2800 for elevated storage tank are less than those by using of finite element method.

To understand how a building responds to earthquakes, it is necessary to know the magnitude and direction of these forces. A structure exposed to seismic excitations cannot be observed in terms of precise characteristics like period, vibration amplitude and so on since the acceleration of ground motion is arbitrary and contains many frequencies.Fourier Integration, however, may transform these accelerations into harmonic functions. As a result of this,to investigate the behaviour of structures exposed to harmonic stimulation and the effects of various factorsin place of a seismic shock.

Using harmonic analysis, tanks of varying sizes were examined.As an illustration, consider the case of a water level of 3 metres.One full glass.



Conclusion:

The base shear force resulting from the structure in pseudo static analysis according to Iranian code/2800 for Empty was found to be:tank is four times as large as those from linear dynamic analysis, and the tank with water is seven times as large.R, the response modification factor, is responsible for the differences.According to the Iranian code/2800, the durations of vibrations are less than in dynamic analysis using finite elements.These discrepancies amount to 27% for an empty tank and 22% for a full tank in this study.with3Water, 2%, for tank with 3 percent2 gallons of water and 27% of the tank's capacity.3. Based on the findings of the analyses of three earthquakes, the base shear force andmagnitude of earthquake displacement is strongly influenced by its frequency content and big earthquakes.This challenge has resulted in a distinction between static and dynamic analysis.In pseudo dynamic analysis, the base shear force is substantially stronger than in static analysis. So that it's more than just a one-time thingThere is no doubt about that.Base shear force and maximum displacement are affected by the vertical component of three accelerograms.We don't need to account for the storage tank since its impact on our calculations is minimal.

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